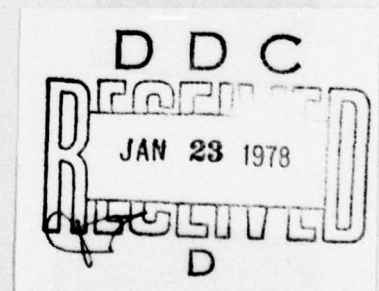FTD-ID(RS)T-1264-77

①

FOREIGN TECHNOLOGY DIVISION

EFFECT OF SIZE AND SHAPE OF SPECIMENS ON THE
FATIGUE LIMIT

by

I. A. Oding

D D C

JAN 23 1978

D

Approved for public release;
distribution unlimited.

FTD- ID(RS)T-1264-77

UNEDITED MACHINE TRANSLATION

FTD-ID(RS)T-1264-77   27 July 1977

MICROFICHE NR: *FTD-77-C-001050*

EFFECT OF SIZE AND SHAPE OF SPECIMENS ON THE
FATIGUE LIMIT

By: I. A. Oding

English pages: 46

Source: Sbornik Dokladov po Dinamicheskoy
Prochnosti Detaley Mashin, Izd-vo
Akademii Nauk SSSR, Moscow-Leningrad,
1946, pp 141-156.

Country of origin: USSR
This document is a machine translation
Requester: AFFDL/FBRD
Approved for public release; distribution unlimited

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.
The use of diacritical marks is preferred, but such marks
may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	A α ɑ	Nu	N ν
Beta	B β	Xi	Ξ ξ
Gamma	Γ γ	Omicron	O o
Delta	Δ δ	Pi	Π π
Epsilon	E ε ϵ	Rho	P ρ ϱ
Zeta	Z ζ	Sigma	Σ σ ς
Eta	H η	Tau	T τ
Theta	Θ θ ϑ	Upsilon	T υ
Iota	I ι	Phi	Φ φ φ
Kappa	K ϰ κ ϗ	Chi	X χ
Lambda	Λ λ	Psi	Ψ ψ
Mu	M μ	Omega	Ω ω

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

———

rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc.
merged into this translation were extracted
from the best quality copy available.

ii

Page 141.

EFFECT OF SIZE AND SHAPE OF SPECIMENS ON THE FATIGUE LIMIT.

I. A. Oding.

1. Introduction.

Into 1929-*1930* Peterson [1, 2] published his investigations of fatigue of metals, manufactured above the specimen/samples whose diameter considerably differed from the diameters of the specimen/samples, which were being usually used for this purpose. The results of these investigations showed that with an increase in the diameter the limit of the fatigue of specimen/samples descends, in particular in those of them, the form which causes stress

concentration. This unexpected conclusion/derivation to very high degree complicated even without that the complex problem of the fatigue of metals. The numerous results of investigations in fatigue of metals of small specimen/samples of those accumulated by that time, were placed in doubt, since to the mechanical engineers it became difficultly of estimating the fatigue strength of its parts whose size/dimensions usually considerably differed from the size/dimensions of the specimen/samples, in which were produced value determinations of the fatigue limits.

The further research done by different researchers, confirmed the conclusion/derivations of Peterson, and scale factor even to larger degree it riveted to themselves attention. It was establish/installed that with an increase in the diameter of specimen/samples the fatigue limit falls not only of the specimen/samples whose form causes stress concentration, but also of smooth specimen/samples, true, to a lesser degree. However, conclusion/derivations from these investigations, coinciding in a qualitative respect, considerably diverged in quantitative readings.

While in the experiments of Faulhaber [3] an increase in the diameter of specimen/samples from 7.5 to 27.3 mm gave a reduction in the fatigue limit for specimen/samples without groove to 6.5-15.5o/o, and for notch test bars - to 33-39o/o, in the experiments of Peterson

and Wahl [4] for notch test bars this reduction was obtained within
limits of 10-20o/o, true, with an increase in the diameter of
specimen/samples from 5 to 50 mm. An even larger reduction is
indicated by Lehr [5, 6], namely to 35o/o with an increase in
the diameter of specimen/sample from 10 to 300 mm.

Peterson [7], investigating smooth specimen/samples, found an
insignificant reduction in the fatigue limit with an increase in the
diameter of specimen/samples. However, in specimen/samples with cross
bores the fatigue limit for a carbon steel with 0.45o/o of carbon
fell by 14.0-20o/o, and for steel with 0.57o/o of carbon - by
29.5-33o/o with an increase in the diameter of specimen/samples from
5 to 76 mm.

These investigations were produced during symmetrical cycle to
bend. Also during symmetrical cycle, but on twisting, scale factor
was investigated by Maylander [8].

Page 142.

For chrome-tungsten steel with an increase in the diameter of
specimen/samples from 14 to 45 mm it was established that a reduction
in the fatigue limit reaches 29o/o, whereupon the greatest reduction
in this case was establish/installed for smooth specimen/samples with

cross bores (28o/o). Smaller reduction for specimen/samples with keyways (24o/o), by fillets (22o/o) and by oblong holes (21o/o).

The analysis of the investigations indicated, quantitative results of which considerably differ from each other, all the same makes it possible to remove the following conclusions of the good-quality character:

a) the reduction in the fatigue limit under the effect of scale factor in some cases was determined in very noticeable dimensions, and in others was little noticeable;

b) with an increase in the unhomogeneity of stress distribution (by increase in the voltage gradient) the effectiveness of scale factor grow/rises; by other owls, scale factor closely related with the form factor of article (groove, fillets, keyways and to that similar forms, calling stress concentration);

c) with the manifestation of scale efficiency factor its is large during a change in the diameter of specimen/samples from 5 to 30 mm; with a further increase in the diameter of specimen/samples the effect of scale factor extinguishes;

d) the quality of material (the tensile figure, damping),

without being sole factor, all the same it has a noticeable effect on the value of the effectiveness of the latter.

These conclusion/derivations not only did not achieve the purpose of scale factor in the problem of the fatigue of metals, but, on the contrary, to extremely high degree they complicated the conditions of the stop of this task: even they began to doubt the usefulness of the investigations of the fatigue of metals produced above specimen/samples with small (5-15 mm) diameters.

It is not necessary, of course, to doubt the usefulness of such machines, which make it possible to experience/test the whole axle/axes of railroad cars or cell/elements of the constructions, about which it is imparted in the articles of academician I. Bardin [9], Teplin [10], Horger and Neifert [11], Timkin [12, 13] and others. However, to consider that only by similar testing machines, which make it possible to experience/test large specimen/samples, one should solve the problem of the fatigue of metals, from our point of view would be extremely faulty. More correct way is to reveal/detect/expose the true reasons, which cause the reduction of the fatigue limit with increase in the size/dimensions of specimen/samples and, being guided by them, to correct test results, obtained above small specimen/samples. This way will not lead us to rise in price even without that the expensive investigations of the

resistivity of the metals of fatigue, but furthermore, it will make it possible more accurately to solve and entire problem of fatigue metals whose urgency for mechanical engineers is completely obvious.

2. Causes of scale factor.

By comparing the opinions of the different researchers, it is possible to see that the reason for a reduction in the fatigue strength with an increase in the diameter of specimen/sample the different researchers explain differently. Now are marked out five basic reasons, by which they are tried to explain the causes of the scale factor:

a) quality is material,

b) voltage gradient,

c) the unhomogeneity of intensity/strength and mechanical properties of microvolumes basted (statistical theory of strength),

d) the total effect of damping and grain size of metal,

e) technology (mode/conditions of cutting) of the preparation of specimen/samples.

Let us examine each of the causes indicated individually.

Page 143.

Quality of material.

It is known that the numerous types of steel, in particular special steel, extremely sensitive change their mechanical properties even with comparatively sensitive they change their mechanical properties even during comparatively insignificant changes in the conditions of heat treatment. In particular is sensitive in this respect the fatigue limit. . For example, Pomp and Hempel [14] impart that chrome-molybdenum steel (0.31 C; 0.96 Cr; 0.23 Mo) in rods 20 and in diameter 60 mm after the oil quenching with one and the same temperature and after identical tempering it showed identical time/temporary resistance to tearing both for the rods 20 mm in diameter (σ = 92.2 kgf/mm²) and for rods 60 mm in diameter (σ = 91.7 kgf/mm²). The limits of fatigue with bend, determined in specimen/samples 7.32 mm in diameter, reveal/detect/exposed already

noticeable difference (Table 1).

It is interesting that of smooth specimen/samples the fatigue limit render/showed above of rod 20 mm in diameter, of notch test bars the fatigue limits they coincided, and of specimen/samples with cross bore, the higher fatigue limit was determined at rod 60 mm in diameter. Let us note that the axle/axis of the specimen/samples, cut out from rod 20 mm in diameter, coincided with the axle/axis of rod. The axle/axis of the specimen/samples, cut out from rod 60 mm in diameter, was furnished approximately in 7 mm from the surface of rod.

These data show that even the uniform heat treatment, but manufactured above the rods (or articles) of different size/dimensions can lead to a noticeable difference in the values of the fatigue limits, without changing in this case the indices of static strength. It is possible that in some investigations, which reveal/detect scale factor, this fact had a value, since frequently technology of manufacture of the initial material, selected for investigation, is described very incompletely. Recall that the sensitivity to heat treatment is especially great of special steels, and namely for these types of steel scale factor was developed most effectively.

However, we assume that to consider this reason as only or decisive would be erroneously. The soft carbonic types of steel does not manifest so noticeable a sensitivity to changes in heat treatment conditions, and nevertheless scale factor is developed in them sometimes by very noticeable form. Furthermore, in a series of works and with special steel the procedure of study was developed so that the effect of changes in the conditions of heat treatment they should consider in them exception/elimination.

The sensitivity of steel to insignificant changes in the conditions of heat treatment should not be disregarded during the analysis of the reasons, which give rise to scale factor, but it and one ought not to assign the exceptional and decisive importance.

Table 1.

(1) Образцы	$\sigma'_w/d = 20$ мм, кг/мм² (2)	$\sigma'_w/d = 60$ мм, кг/мм² (2)	$\dfrac{q'_w/d = 20}{\sigma'_w/d = 60}$
Гладкие . . (3) . .	51.0	47.0	1.09
С выточкой . (4) .	25.0	25.0	1.00
С поперечным отвер- стием . . . (5) .	27.5	31.0	0.89

Key: (1). Specimen/samples. (2). kgf/mm². (3). Smooth. (4). With groove. (5). With cross bore.

Page 144.

Stress differential.

The supporters of assumption about the preferred effect of stress gradient determine the role of the latter of themes by the fact that with equal voltage/stresses on surface layer of specimen/sample with larger diameter the voltage gradient will be less, and consequently, must decrease the effectiveness "lifting

forces", which will be the greater, the sharper change in stress over the section/cut of specimen/sample. It is natural that with increase in the diameter of specimen/sample the voltage gradient is decreased; is decreased the effectiveness "lifting forces" and, therefore, must be decreased the value of the fatigue limit.

In notch test bars, the effectiveness of the effect of the diameter of specimen/samples on the fatigue limit is considerably higher than in smooth specimen/samples. But since in notch test bars, as a result of the stress concentration, change in the voltage gradient it is more than of smooth specimen/samples, a larger reduction in the fatigue limit in notch test bars finds here a good explanation in the factor of voltage gradient.

By this voltage gradient Koontz [15] it explains an increase in the yield points and fatigue of notch test bars, but Afanas'yev [16] - the difference between the theoretical and real stress concentration factors during testing on got tired notch test bars.

I do not divide this hypothesis, since difficult to present the mechanism of the action/effect of these "lifting forces". Why the layer of grains of metal, which experience/test elastic deformation, must prevent the course of plastic deformation the adjacent layer of grains, strained beyond elastic limit, to me it is incomprehensible.

And, even Allow/assuming this effect, it is difficult to answer the question, why the uniformly strong metals which have identical hardness, the equal tensile figures and elastic properties, completely differently react to the presence of groove and the scale factor.

Therefore I assume that one should hardly consider consider the stress differential as reason, which gives rise to scale factor.

Static theory of strength.

Recently some researchers solved the problem of the brittle and fatigue strength of metals, and together with it and the task of scale factor with the aid of statistical theory. . The first attempt at the quantitative solution to this question by statistical method belongs to Weibull [17]. Then by this solution was occupied Kontorova [18], theory of whom it was modernized in work by Kontorova and Penkel' [19]. If the authors of the works indicated relate their conclusion/derivations to the brittle strength of real crystals, without being stopped in this case directly on fatigue strength, then in the work of Afanas'yev [21, 22], which is the development of Orowan's work [20], statistical theory is utilized for the direct/straight solution to the problem of fatigue strength.

The authors of the statistical theory of strength construct their conclusion/derivations exclusively on the unhomogeneity of intensity/strength and mechanical properties of the microvolumes of metal, being given relationships between the size/dimensions of this unhomogeneity and using for quantitative solution during position of theory of probability.

Page 145.

This new method of the solution to the problem of the strength of metals indisputably must play very large role. It can become very powerful implement in the hands of the researcher-metallographers and explain many facts, which without this method can remain those which were not explained or even not detected. Even now qualitatively the results of pointed out above studies coincide with a series of experimental data; their conclusion/derivations show that the fatigue strength must be decreased with an increase in the size/dimensions of specimen/samples, with an increase in the size/dimensions not only cross section, but also length. The effect of the latter on the fatigue limit up to now experimentally still not was studied.

However, it is necessary to warn, that the attempt to explain

the generation of scale factor one only by unhomogeneity of intensity/strength and mechanical properties of the microvolumes of metal can lead to false results. Therefore the comparison of the conclusion/derivations of the statistical theory of strength with the results of the experimental data, the procedure of which was not free from the effect of other factors, not taken into account by statistical theory, it cannot be convincingly even during the very good coincidence of the results of these experiments with the types of statistical theory.

Rightly to existence they have the only such hypotheses, which, in the first place, do not place the researchers on false way and, in the second place, they do not blunt, but, on the contrary, they sharpen the attention of the researchers to the different factors, which are powerful of having one value or the other in the solution of this problem.

Now difficult even from the available data to establish/install quantitative effect of the unhomogeneity of the mechanical properties of the microvolumes of metals in the task of scale factor in the problem of fatigue of metals. For this is required the new investigations, carried out taking into account other numerous reasons, which give rise to scale factor. Only after this it will be possible to establish does encompass statistical theory

DOC = 77126401   PAGE ⬤

quantitatively most important reasons.

The effect of cyclic viscosity and metal grain size

One of the reasons, which give rise to scale factor, Oding [23] counts the total effect of the cyclic ductility/toughness/viscosity and grain sizes it basted. This theory can be briefly presented as follows. During a nonuniform distribution of voltage/stress the most strained soya of metal experience/test elasto-plastic strain, if, of course, load causes stress, equal or larger than the fatigue limit.

Thickness $r-\rho_w$ the elasto-plastic deformed layer (Fig. 1) with the load, which causes the voltage/stress, equal to the limit of fatigue (for example, for the case of twisting), depends on the values: 1) cyclic ductility/toughness/viscosity, i.e., the width γ_w. The hysteresis loop measured during the first cycles, 2) modulus of shear G even 3) the limit of fatigue with pure shear τ_w:

$$\rho_w = r \cdot \frac{\tau_w}{\tau_w + \varphi \gamma_w}. \qquad (1)$$

These values do not depend on the size/dimension of specimen/sample, and therefore the fatigue limit during twisting τ_w' (Fig. 1)

$$\tau_w' = \tau_w \left(4/3 - 1/3 \frac{\rho_w^3}{r^3} \right) \tag{2}$$

also must not depend on the size/dimension of specimen/sample.

Page 146.

However, the computed value ρ_w is inaccurate (theoretical) on the strength of the following considerations. Plastic deformation, unlike the elastic, is spread completely to the whole grain. It is not possible to itself to present part of one grain the plastically deformed zone, strictly speaking, will not be equal to difference $(r - \rho_w)$, will be more its not value, approximately equal or to the smallest diameter of grain Δr. On the strength of this, the fatigue limit during twisting will be determined equal not to value τ_w'; a to larger value τ_w''. The latter depends on the size/dimension of specimen/sample, since equation (2) will be rewritten now in the following form:

$$\tau_w'' = \tau \left[4/3 - 1/3 \frac{(\rho_w - \Delta r)^3}{r^3} \right]; \tag{3}$$

and in it term $\frac{(\rho_w - \Delta r)^3}{r^3}$ will depend not only on relation ρ_w/r, the not reflecting scale factor, but also the ratio $\Delta r/r$, which reflects this factor. With an increase in the radius of specimen/sample the last/latter relation will be decreased, since for the

assigned/prescribed material Δr = const. Consequently, will decrease value τ_o''.
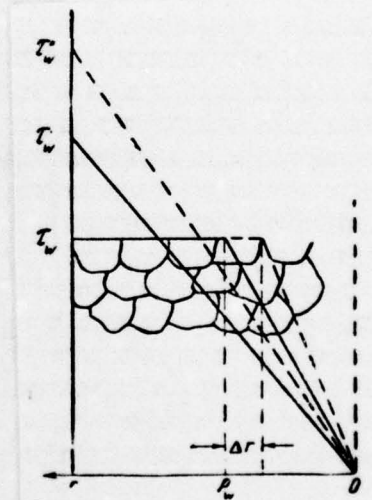
Easy to see that if the size/dimension of transverse of grain is commensurable about by the thickness of the plastically deformed layer of specimen/sample, then grain size has a noticeable effect on the value of the fatigue limit. Consequently, those metals which have low damping and coarse grain, more effective develop scale factor than metals with larger damping and small grain.

These conclusion/derivations will agree well with the results of experiments, just as the quantitative side of this theory. Furthermore, this theory very well elucidates, why with an increase in the voltage gradient is reinforced the effectiveness of scale factor, since an increase in the voltage gradient, a feast other equal conditions, leads to decrease in the thickness of the elastic-plastically deformed layer.

The presence of the plastically deformed layer, and together with it and the reduction of ceiling voltage with a heterogeneous distribution of the latter is disproved in the conclusions of the works of Shaal [24]. Together with this, as a result, must also be confirmed the theory of the generation of scale factor outlined above. However, it seems to us that the conclusion/derivations of

Shaal are groundless. It measured the stress level on of channels
with X-ray photographic method at static and cyclic twisting greasy
and duralumin specimen/samples. In this case to them it was
established that the ceiling voltage was not quenched up to stress
that caused a breakage in the specimen/sample. Strictly speaking, a
reduction in the ceiling voltage them is reveal/detected, since with
a specimen/sample of diameter $2r = 24.2$ mm radius fillets $\rho = t =$
1.75 mm the stress concentration factor to them was $\alpha_k = 1.28$,
establish/installed equal to $\alpha_k = 1.65$, instead of the theoretical
according to the data of Oding [25], $\alpha_k = 1.50$, on the data of Tum and
Bautse [26], and $\alpha_k = 1.35$, according to the calculation according to
the theory of Zonntag [27].

Figure 1.

Page 147.

But even in such a case, when X-ray analysis did not reveal/detect
reduction ceiling voltages, could not be negated the presence of
plastic deformation in separate grains, since the presence in the
elasto-plastic deformed layer of the grains, deformed by purely

elastic, must find its reflection on X-ray photograph. Consequently,
it cannot be counted that by the works of Shaal proved generally the
absence of the plastically deformed grain and elastic-plastic
deformed layer of metal, but together with it and the absence of
reduction ceiling voltages.

Technology of the manufacture of specimen/samples.

The great effect, exerted by technology of the manufacture of
specimen/samples to the fatigue strength, was still reveal/detected
into 1911 researchers Eden, Rose and Cunningham [28], in which it was
for the first time shown, which even insignificant flaw/defects on
the surface of specimen/sample in the form of small scratches very is
noticeably reduce the fatigue limit even of the soft types of steel.

This phenomenon intensely studied, but it is necessary,
unfortunately, to state that with the solution of this task was
extremely narrowed. Instead of the analysis of wide task - the effect
of the mode/conditions of cutting in fatigue strength, actually the
analysis came to research on the effect of surface condition on
fatigue strength. But meanwhile the number of experiments showed that
the machining introduces very substantial changes in the properties

of surface layer of article, which they cannot but be reflected in
the indices of fatigue strength. For example, Rutman [29] showed that
with turning processing in article appear the residual stresses whose
value and sign can fluctuate in very considerable size/dimensions.
Analogous results report Khenriksen [30], which investigated the
residual stresses, which were being received with planing.

The presence of peening in the surface layer of article after
machining by proved magnetic measurements in the work of Oding [31]
and by X-ray analysis in the work of Sergeyev [32], and also by the
investigations of Selisskiy [33] and of Kravchenko, Selinsskiy and
Tyulenev [34].

Finally, the effect of surface peening from machining on the
limit of fatigue of steel studied Shevandin Kaganovich [35], and also
Leyensetter [36], which showed that with a change in the
mode/conditions of cutting the fatigue limit can be changed by very
noticeable form.

All these investigations indicate that machining metals by chip
removal is not a process, which only imparts to article the specific
size/dimensions and form. On the contrary, this process just as heat
treatment and hot machining, has a very powerful effect on properties
it basted, more precise to the properties of surface layer. But since

DOC = 77126401   PAGE ●

the latter in the majority of cases it causes the fatigue strength of article, obviously that the mode/conditions of cutting, including here speed and the depth of cutting, supply/feed, the geometry of cutting tool, etc., must have a very essential effect on fatigue strength.

Effect, exerted to metal by machining, very complex. In the process of removal/taking the spokeshaves occur at least three phenomena on surface layer, which in sum cause at least eight factors, which affect the limit of the fatigue of metals, increasing or after reducing it.

Page 148.

These phenomena are the following:

a) the plastic deformation of surface layer,

b) heating surface layer,

c) the formation of relief on surface.

a) the plastic deformation of surface layer includes three factors (see Table 2), that influence the limit of fatigue: the

degree of peening α_1, the depth of work-hardened layer β_1, the value
of residual stresses γ_1.

With an increase in the degree of peening it is possible,
according to the available numerous results of investigations (see,
for example Oding, Yefremov [37]), to assume that the fatigue limit
is increased.

An increase in the thickness of work-hardened soya must lead
also to an increase in the limit of fatigue with bend and twisting
until the thickness of that work-hardened layer exceeds the thickness
of the elastic-plastically deformed layer, caused by cyclic stress.
The further thickening of work-hardened soya must not be reflected in
the value of the limit of fatigue at bend and twisting.

An increase in the fatigue limits by factors α and β in Table 2
is reflected by rifleman/pointers, directed upward.

The residual stresses, caused by surface peening, are those
compressive on surface and stretching to the center of
specimen/sample. They create asymmetrical cycle (with the acting
symmetrical cycle), mean voltage/stress of which is the compression
stress.

If tangential and axial residual surface stresses of cylindrical specimen/sample are equal, then they do not increase the value of the fatigue limit during twisting, since it is known that the bilateral compression in surface layer does not produce an increase in shearing stresses on shear planes. With the inequality of tangential and longitudinal stresses the residual stresses will lead to an amplitude reduction of stress during twisting, and therefore the limit of fatigue during twisting will descend.

The presence of tensile average stress in the center of specimen/sample must lead also to a reduction in the fatigue limit with elongation - compression.

The limit of fatigue with bend can be increased and can be reduced, since it is known that the compressive average stress with bend it can increase and decrease the amplitude of stress.

b) heating surface layer includes three factors (see Table 2), that influence the limit of fatigue; α_2 - the value of residual stresses, β_2 - the degree of aging; γ_2 the degree of softening.

The residual stresses, which can arise due to excessive heating surface soya, will be those which stretch from surface and those compressive in the center of specimen/sample. Consequently, they form

asymmetric cycle (during the symmetrical acting cycle) with tensile average stress, which must lead to a reduction in the amplitude of stress and, therefore, to a reduction in the determined fatigue limits with elongation - compression, bend and twisting.

The aging surface work-hardened soya, unavoidable during the average heatings, must, as a rule, lead to an increase in the fatigue limits.

Higher heatings lead to softening the work-hardened soya, which will involve a reduction in the fatigue limits.

c) the formation of relief on the machined surface will entail a reduction in the limits of fatigue and themes to larger degree, than more α_3 - the depth of the traces of cutter, β_3 - the sharpness of the traces of cutter.

Page 149.

From that which was presented it is evident that the treatment
by chip removal gives rise to large number, the factors, one part of
which produces increase in the fatigue limits, and another - a
reduction in these strength characteristics.

It is interesting to explain, which effect have the parameters,
which determine the mode/conditions of cutting, in the effectiveness
of that or different of eight of examined factors.

For the parameters, which determine the mode/conditions of
cutting, let us accept speed and the depth of cutting and supply/feed
(leaving aside the geometry of cutting tool, condition of cooling,
etc.).

The effect of these parameters on the factors, which affect the
value of the fatigue limits, is studied very little. It is possible
to state/establish even that the effect of cutter on the surface of
workpiece almost in no way was studied. Therefore to the given in
Table 2a data one should relate as the first attempt to examine this
extremely urgent question.

Let us examine first of all the effect, exerted by the parameters of the mode/conditions of cutting in plastic deformation. According to the results of the investigation of Kravchenko, Selisskiy and Seal [34], it is possible to count that an increase in the cutting speed leads to decrease in the thickness of work-hardened layer (β_1) of workpiece. An increase in the supply/feed and depth leads to opposite results - thickness of the layer is increased. About the effect of these parameters of the mode/conditions of cutting in the degree of peening I it could not find indications in the literature, but it is possible to assume that the degree of peening (α_1) and, consequently, also value of residual stresses (γ_1) will be changed in the same direction that i the thickness of the work-hardened layer.

On heating surface layer depending on the parameters of conditions of cutting very interesting data are acquired in the investigations of Oding [38].

Table 2. Factors of cutting, which affect the fatigue limit.

Явления при резании (1)	Факторы, влияющие на величину пределов усталости (2)	Пределы усталости (3)		
		растяжение — сжатие (4)	изгиб (5)	кручение (6)
а) Пластическая деформация (7)	α₁ Степень наклепа (8)	↑	↑	↑
	β₁ Толщина наклепанного слоя (9)	↑	↑	↑
	γ₁ Величина остаточных напряжений (10)	↓	↑↓	↓
б) Нагрев поверхностного слоя (11)	α₂ Величина остаточных напряжений (12)	↓	↓	↓
	β₂ Степень старения (13)	↑	↑	↑
	γ₂ Степень размягчения (14)	↓	↓	↓
в) Рельеф поверхности (15)	α₃ Глубина следов резца (16)	↓	↓	↓
	β₃ Острота следов резца (17)	↓	↓	↓

↑ Фактор повышает предел усталости (18)   ↓ Фактор понижает предел усталости (19)

Key: (1). Phenomena with cutting. (2). Factors, which affect the value of fatigue limits. (3). Fatigue limits. (4). elongation is compression. (5). bend. (6). twisting. (7). Plastic deformation. (8). Degree of peening. (9). Thickness of work-hardened soya. (10). Value

of residual stresses. (11). Heating surface layer. (12). Value of
residual stress. (13). Degree of aging. (14). Degree of softening.
(15). Relief of surface. (16). Depth of the traces of cutter. (17).
Sharpness of the traces of cutter. (18). Factor increases the fatigue
limit. (19). Factor reduces the fatigue limit.

Page 150.

It found that with an increase in the speed of cutting and rate of
feed the temperature on the surface of workpiece is decreased. With
an increase in the depth of cutting the temperature on the surface of
workpiece is increased. These results make it possible to come to the
conclusion that with an increase in the cutting speed and supply/feed
will reduce the value of residual stresses, the degree of aging and
the degree of softening.With an increase in the depth of cutting the
effectiveness of these factors, on the contrary, will be increased.

Finally, it is possible to consider that the purity/finish
(quality) of the surface will be improved with an increase in the
cutting speed and to deteriorate with an increase in supply/feed and
depth of cutting.

The given very short and far incomplete analysis shows that the

mode/conditions of processing metals as chip removal has great effect

on the fatigue strength of metals and must play the significant role

in the question concerning scale factor. By no means it is

indifferent, as are made specimen/samples, since even during the

completely identical mode/conditions of cutting the effect of the

latter will be different, if in one case turned specimen/samples 5 mm

in diameter, a v drugom diametrom 50 or 100 mm. Completely different

will be also effect from that work-hardened soya by thickness, for

example, 0.5 mm, if in one case specimen/sample has diameter of 5 mm,

and in other 50 mm.

But it is possible with large improvement to confirm which in

the majority of studies of fatigue of metals either entirely or is

very small amount of attention turned to the methods of the

manufacture of specimen/samples, if we exclude from this concept the

quality of surface from the viewpoint of its relief.

I assume that this factor, perhaps, is most effective of all

other factors, which give rise to scale factor.

3. Experimental investigation of scale factor.

For the purpose of the determination of the effectiveness of that or different of the reasons, that gives rise to scale factor, us was undertaken one, but still not the final study, preliminary results of which are set forth below.

As material served structural steel of brand 30 v the normalized state (C 0.29o/o, Mn 0.59o/o, Si 0.20o/o, S 0.05o/o, P 0.03o/o), mechanical properties of which: yield point 36.6 kgf/mm², the tensile figure 62.0 kgf/mm², elongation per unit length (δ_s) 22.7o/o, the compression of the area of cross section 44o/o, Brinell hardness 156.

Table 2a. Effect of the parameters of the mode/conditions of cutting
in the factors, which affect the value of limits of fatigue.

Параметры режима резания (1)	Пласт. деформация (2)			Нагрев (3)			Рельеф (4)	
	α_1	β_1	γ_1	α_2	β_2	γ_2	α_3	β_3
Скорость резания . . .(5).	↓	↓	↓	↓	↓	↓	↓	↓
Подача . . . . (6). . .	↑	↑	↑	↓	↓	↓	↑	↑
Глубина резания . . .(7). . .	↑	↑	↑	↑	↑	↑	↑	↑

↑ — увеличение параметра резания (8)
повышает α, β, γ

↓ — увеличение параметра резания (9)
уменьшает α, β, γ

Key: (1). Parameters of the mode/conditions of cutting. (2). Layer.
deformation. (3). Heating. . (4). Relief. (5). Cutting speed. (6).
Supply/feed. (7). Depth of cutting. (8). an increase in the parameter
of cutting increases α, β, γ. (9). an increase in the parameter of
cutting decreases α, β, γ.

Page 151.

The microanalysis of the longitudinal and cross sections did not
reveal/detect any peculiarity or flaws in this steel. From flanges of

steel are made two series of specimen/samples for fatigue test during symmetrical twisting in the electromagnetic machine of eng. V. K. Dobrer's system. In each series were the specimen/samples of three groups of different diameters (6, 10 and 13 mm).

The specimen/samples of both series were formed on strictly established/installed mode/conditions, namely: cutting speed 15 m/min, the depth of cutting 1 mm, supply/feed 0.5 mm-revs.

In order to eliminate the effect of surface condition on the limit of fatigue (but surface after the treatment indicated was obtained roughly), specimen/samples additionally they were subjected to the removal of one additional chip during the mode/conditions: cutting speed 15 m/min, the depth of cutting 0.15 mm, supply/feed 0.05 mm-revs.

By this re-treatment were eliminated the surface traces of the preceding/previous treatment. Then the samples of the first series were subjected to trimming small emery cloth, as a result of which surface was obtained sufficiently pure/clean.

The specimen/samples of the second series after additional treatment were tempered in vacuum (pressure 0.01 mercury columns) at by 600°, 3-hour holding after heating. The target/purpose of this

operation consisted in the removal of residual stresses and peening, obtained as a result of machining. After this operation the specimen/samples of the second series were cleaned by emery cloth analogous with the specimen/samples of the first series.

The determination of the limits of fatigue was manufactured by the method of selector on base 8 million cycles. The results of these tests are given in Table 3 and in Fig. 2. They make it possible to make the following conclusions:

1) scale factor was revealed only of the specimen/samples, not to tempered;

2) scale factor in no way was revealed in the specimen/samples, to tempered. This can be explained comparatively small grain they became, obtained after standardization, and high cyclic ductility/toughness/viscosity of tested steel, since it is known that the carbon steel with content of 0.3-0.35o/o of carbon possesses very high cyclic ductility/toughness/viscosity.

Consequently, of five reasons, which give rise to scale factor, in these tests they were not revealed: a) the quality of material, b) the voltage gradient, c) the unhomogeneity of the mechanical properties of the microvolumes of metal (static theory of strength).
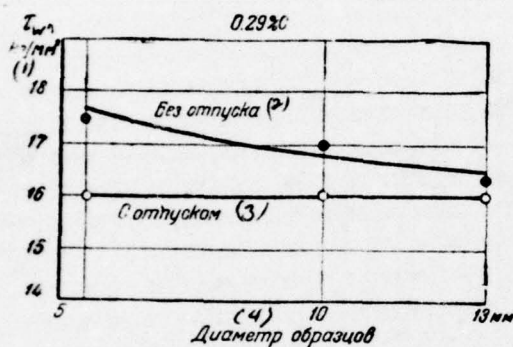
Fig. 2.

Key: (1). kgf/mm². (2). Without tempering. (3). With tempering. (4). Diameter of specimen/samples.

Page 152.

The effectiveness of technological reason is revealed according to these results completely distinctly. To assume that the tempering could cause at least small decarbonization surface soya of

specimen/samples, does not feel, since even in this case scale factor

must be revealed at the tempered specimen/samples, since the

conditions of tempering for all specimen/samples were strictly

identical.

The results of these tests also not contradict the hypothesis of

the total effect of damping and grain sizes of metal, since, as noted

above, this steel possessed small grain and high cyclic

ductility/toughness/viscosity.

The following stage of investigations led us to even more

interesting results. Unlike the first, in these investigations was

determined the fatigue limit with symmetrical bending on base 10

million cycles, for which they were used two machines - the firm of

Schenk and his own manufacture of the same system. Steel was chosen

again carbonic, but with the smaller carbon content, than in the

first, for the purpose of a reduction in cyclic

ductility/toughness/viscosity. Its chemical composition: C. 0.16o/o,

Mn 0.55o/o, Si - traces, S 0.052o/o, P 0.038o/o.

Steel was subjected to standardization, whereupon for the first

three series of specimen/samples (Table 4) standardization was

manufactured for the purpose of obtaining small grain, and for the

subsequent three series standardization was produced with

superheating for the purpose of obtaining coarse grain.
Microphotography/microphotographs of steel in both states are
represented in Fig. 3 and 4.

From both groups became were made cylindrical samples of 6, 10
and 13 mm in diameter in the identical parameters of the cutting:
cutting speed v = 20-22.5 m/min., supply/feed 0.05 mm-revs the depth
of cutting 0.5 mm; the surface of specimen/samples was cleaned by
small emery cloth. In such type of specimens (series III and IV) were
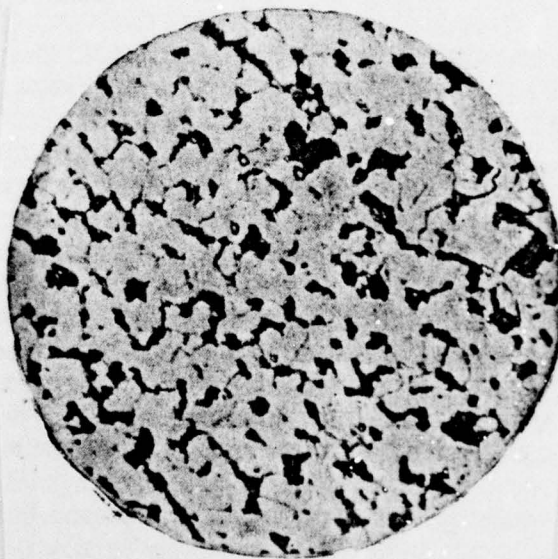subjected to fatigue test.

Fig. 3.

DOC = 77126402　　　　PAGE

Table 3. The results of fatigue test during symmetrical twisting became 30 in smooth specimen/samples 6.10 and in diameter 13 mm.

(1) Обработка	(2) Предел усталости τ'_{ω}, кг/мм²		
	$d = 6$ мм	$d = 10$ мм	$d = 13$ мм
Без отпуска . (3) . .	17.5	17.0	16.3
С отпуском . . (4) . .	16.0	16.0	16.0

Key: (1). Treatment. (2). Limit of fatigue　　kgf/mm². (3). Without tempering. (4). With tempering.

Page 153.

For series I, II, IV and V, the specimen/samples were made with groove. The radius of rounding ρ and the depth of groove were accepted equal to one by the tenth from the radius of specimen/sample in its fine/thinnest part, i.e., $\rho = t = 0.1r$.

Groove was prepared at the following cutting speeds:

(1) для диаметра		(2) скорость резания		(3)
для диаметра $d = 6$ мм	скорость резания	$v = 15$	м/мин	
" " $d = 10$	" "	"	$v = 11$	"
" " $d = 13$	" "	"	$v = 2.8$	"

Key: (1). for a diameter. (2). cutting speed. (3). m/min.

Supply/feed was manufactured by hand, very low value, to establish which for us did not manage.

After these operations the specimen/samples of series I and IV were tested to fatigue. The specimen/samples of series II and V underwent even additional tempering at 580-600° during 3 hours. Tempering was manufactured in specially designed by eng. A. S. Michealson box with double cap/cover. Between case lids spurt out pig iron drinking fountains, which prevent the penetration of atmospheric oxygen into that part of the box, into which are placed the specimen/samples. With this tempering, which has larger convenience in comparison with relaxation in vacuum, the surface of specimen/samples it acquires blue temper color.

In order to be convinced in the absence of decarbonization they began from the surface of specimen/samples with this method of tempering, we took using the method of Shevaldin and Kaganovich [35] hardness measurement of the surface of some specimen/samples according to Vickers feast to the different value of load. one of such measurements it is given in Table 5. It testifies to the full/total/complete absence of decarbonization of surface layer of specimen/samples. Actually, if this decarbonization occurred, then

readings of hardness with load of 1.0 kg. must be less than reading
hardness with load 5 kg. This is not observed. A reduction in the
hardness with large loads of 20 and 50 kg. is explained by additional
deformation it basted at the place of impression, since the
indentation of diamond pyramids was manufactured to the cylindrical
surface of specimen/sample.

Establish/installing during the manufacture of groove high
cutting speed for specimen/samples with a small diameter and lower
speed for specimens with large diameter, we they were guided by the
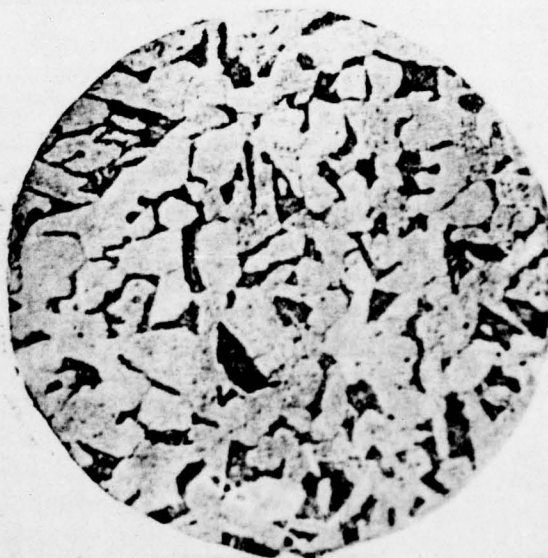following considerations.

Fig. 4.

Page 154.

Simple observation in the shop, which prepares specimen/samples for fatigue test, made it possible to establish that, as a rule, specimen/samples with larger diameter are machined by turners at high cutting speeds, than specimen/samples with smaller diameters. Therefore, after suspecting, that the cutting speed can be the real factor, which lowers the fatigue limit of specimen/samples with large diameter, was decided to artificial to change the routine of the manufacture of specimen/samples. Our suspicions justified. Being turned to these Fig. 5 and 6 and Table 4, it is possible to make the following conclusions:

1. Scale factor was not revealed in the smooth specimen/samples, not equipped with groove. This result is located in full/total/complete coordination with the results of Peterson's indicated studies. Taking into consideration that the transition from cylindrical part to the knob/caps of specimen/samples was done with the aid of fillets whose radius was accepted equal to

$$
\begin{aligned}
&(1)\text{для образцов диаметром} & d &= 6 \text{ мм} & r_g &= 6 \text{ мм,} \\
&\text{"} \quad\quad \text{"} \quad\quad \text{"} & d &= 10 \text{ "} & r_g &= 10 \text{ "} \\
&\text{"} \quad\quad \text{"} \quad\quad \text{"} & d &= 13 \text{ "} & r_g &= 13 \text{ "}
\end{aligned}
$$

Key: (1). for specimen/samples by diameter.

it is possible to count that for the articles made of low-carbon

steel, which have similar fillets, the scale factor is not developed, if specimen/samples are made with the identical mode/conditions of cutting.

2. Scale factor very sharply appeared in untempered after mechanical processing of specimen/samples, equipped with groove, in particular of the specimen/samples of those normalized to small grain.

Table 4. Test results for fatigue with symmetrical cycle for the bending of steel 15 in smooth notch test bars 6, 10 and in diameter 13 mm.

(1) Серия	(2) Форма образцов	(3) Термическая обработка	(4) Обработка поверхности	(5) Предел усталости кг/мм²		
				$d=6$ мм	$d=10$ мм	$d=13$ мм
I	(6) С выточкой	Нормализация на мелкое зерно	Механич. обработка без отпуска	9.0	10.0	13.5
II	(9) То же	(7) То же	(10) Механич. обработка с отпуском	12.0	—	12.0
III	(11) Гладкий	"	Механич. обработка без отпуска	22.0	21.5	22.0
IV	С выточкой		(8) То же	11.8	—	13.2
V	То же	(12) Нормализация на крупное зерно	(10) Механич. обработка с отпуском	12.5	—	12.2
VI	Гладкий		(8) Механич. обработка без отпуска	—	—	21.0

Key: (1). Series. (2). Form of specimen/samples. (3). Heat treatment. (4). Surface treatment. (5). Fatigue limit kgf/mm². (6). With groove. (7). Standardization to small grain. (8). Mech. treatment without tempering. (9). The same. (10). Mech. treatment with tempering. (11). Smooth. (12). Normalization to coarse grain.

Table 5. Vickers hardnesses after the tempering of steel 15 at
580-600° during 3 hours in box with double cap/cover.

(1) Измерение	(2) Нагрузка, кг				
	1	5	10	20	50
I	124	127	122	108	106
II	126	126	123	107	107
III . . . . :	127	124	122	108	109
IV	125	124	124	108	106
(3) Ср. значение твердости	125	125	123	108	107

Key: (1). Measurement. (2). Load, kg. (3). Comp. hardness value.

Page 155.

However, the manifestation of scale factor in this case is directed
to opposite side in comparison with previously established/installed
direction of another study. Namely, in our investigations the fatigue
limit was not lowered, but on the contrary, it was raised with an
increase in the diameter of specimen/samples.

3. In the tempered specimen/samples, equipped with groove, scale
factor was not revealed at steel, normalized to small grain, and very
weakly it was revealed at steel with coarse grain, whereupon - in
common direction, i.e., the fatigue limit was lowered at
specimen/samples with large diameter. Consequently, the theory, which
allow/assumes the generation of scale factor as a result of the total
effect of damping and grain size, found in these experiments its
reflection. Effect, truth was obtained insignificantly, but also

difference in the grain size of steel also was largest. The
effectiveness of the manifestation of scale factor here it was
revealed in all by the value of order 4-5o/o. But simple calculations
make it possible to establish that the effectiveness of the total
effect of damping and grain size on scale factor can reach in the
most favorable cases of 10-15o/o.

4. Technological factor was revealed in these studies especially
effectively. It even in state to invert of a change of the values of
the limits of fatigue, increasing the latter in specimen/samples with
large diameter and lowering them in specimen/samples with a small
diameter. That this result is obtained as a result of the effect of
technological factors, testifies that fact that the tempered
specimen/samples not lead to scale factor or revealed it in reverse
direction. Consequently, scale factor in that sense, kA it it is
accepted to now understand, it can be developed with very
insignificant effectiveness as a result of the total effect of
damping and grain size of metal. Considerably greater effectiveness
is developed by technological factor, and the observed by the
different researchers considerable decrease in the values of the
fatigue limits with an increase in the diameter of specimen/samples
one should, apparently relate not because of scale factor, and
because of the technological factor, not taken into account in their
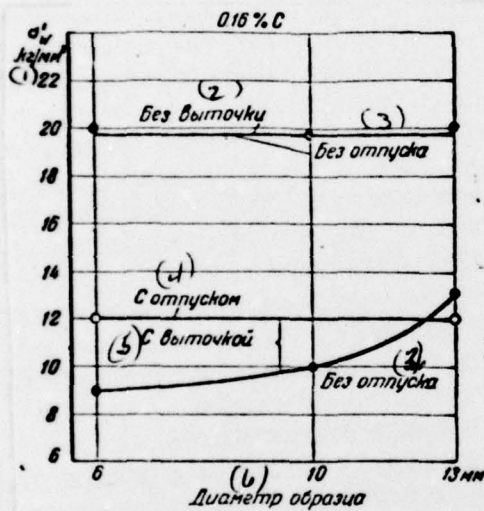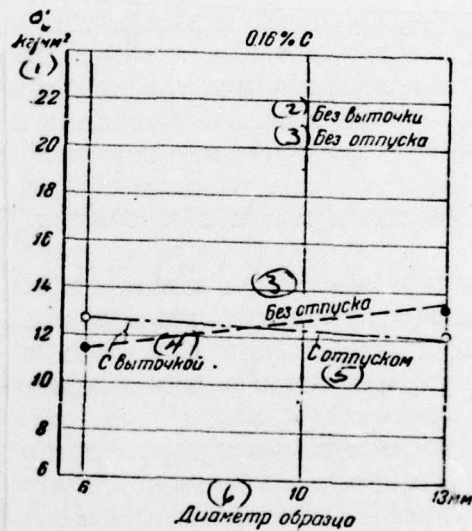studies.

Fig. 5.

Fig. 6. Key next page.

Key: (1). kgf/mm². (2). Without groove. (3). Without tempering. (4). With tempering. (5). With groove. (6). Diameter of specimen/sample.

Key: (1). kgf/mm². (2). Without groove. (3). Without rest. (4). With groove. (5). With tempering. (6). Diameter of specimen/sample.

Page 156.

5. According to the obtained results of studies could not be established any effect on the generation of the scale factor of quality of material, voltage gradient and unhomogeneity of the mechanical properties of the microvolumes of metal (statistical theory of strength). If similar effect the reasons indicated have, then effectiveness its is less than that accuracy/precision, with which we establish/installed the values of the limits of fatigue (0.3 kgf/mm²).

6. Cold working of metals by chip removal has a very effective effect on the value of the fatigue limits, and, therefore, it cannot be already considered as operation, which imparts to metal the only

corresponding size/dimensions and form. It is also the operation,
which imparts to article the determined properties (fatigue
strength). It is necessary therefore to study effect on the fatigue
strength of all factors causing the mode/conditions of cutting, in
order to obtain possibility to establish/install not only
economically advantageous mode/conditions, but also the
mode/conditions, which impart to article highest strength.

REFERENCES.

1. R. E. Peterson. Proc. ASTM, p. 371—380 (1929).
2. R. E. Peterson. Trans. Am. Soc. Stl. Treat., p. 1041—53 (1930).
3. R. Faulhaber. Mitt. Forsch. Inst. V. Stahlwerke A. G. Dortmund 3, 6, (1933), St. u. Eis., S. 1106 (1933).
4. R. Peterson, A. Wahl. J. Appl. Mech., № 1 (1936); рефер. Вестн. металлопромышл., № 11 (1937).
5. E. Lehr. Techn. Ztrbl. prakt. Metallbearb. H. 17—20 (1937).
6. E. Lehr. Metallwirtschaft, № 27. 595—99; № 28, 617—23 (1939).
7. R. E. Peterson. Trans. ASME, APM. 55, 11 (1933).
8. R. Mailaender. Techn. Mitt. Krupp, p. 143—152 (1931).
9. И. Бардин. Сталь, № 8, стр. 48—54 (1937).
10. R. L. Teplin. Proc. ASTM, 39, 711—22 (1939).
11. O. I. Horger and H. R. Neifert. Proc. ASTM, 39, 723—40 (1939).
12. Timkin. Trans. ASME (1938).
13. Timkin. Heat a. Treating a. Forging (1939).
14. A. Pomp, M. Hempel. Arch. Eisenhüttenwesen, № 8, 403—14 (1940—1941).
15. W. Kuntze. Der Stahlbau, № 2 (1935).
16. Н. Н. Афанасьев. ЖТФ, 6, 8 (1936).
17. Weibull. Proc. Roy. Swedish Inst. Eng. Res., № 151 (1939).
18. Т. А. Конторова. ЖТФ 10, 886 (1940).
19. Т. А. Конторова, Я. И. Френкель. ЖТФ 11, 173 (1941).
20. E. Orowan. Proc. Roy. Soc., Ser. A, 171, № 944, 79 (1939).
21. Н. Н. Афанасьев. ЖТФ 10, 1553 (1940).
22. Н. Н. Афанасьев. ЖТФ 11, 341 (1941).
23. И. А. Одинг. Вестн. металлопромышл., № 12 (1938).
24. A. Schaal. Ztschr. Techn. Phys., № 1, 1—7 (1941).
25. И. А. Одинг. Усталость металлов и задачи машиностроения. Лнгр. (1941).
26. A. Thum, W. Bautz. Ztschr. VDI, № 78, 17 (1934).
27. R. Sonntag. Ztschr. angew. Math. u. Mech. 9, 1 (1929).
28. Eden, Rose, Cunningham. Proc. Inst. Mech. Eng. Oct. (1911).
29. W. Ruttman. Techn. Mitt. Krupp, H. 3, Juni 1936.
30. E. Henriksen. Ingeniervidenskabilige Skrifter A, № 43 (1937); Kopenhagen, Maschinenb. Betr. № 17—18, 457—58 (1938).
31. И. А. Одинг. Электричество, № 17—18 (1929).
32. С. В. Сергеев. Сб. статей „Рентгенография в применении к исследованию материалов", стр. 384—87. ОНТИ, 1936.
33. Я. Селисский. Заводская лабор., № 6, стр. 674 (1935).
34. Н. Кравченко, Я. Селисский, В. Тюленев. Заводская лабор., № 9, стр. 1085 (1936).
35. Е. Шевалдин и И. Каганович. Техн. физ. 10, 295 (1940).
36. W. Leyensetter. Ztschr. VDI, № 52 (1933).
37. И. А. Одинг, А. И. Ефремов. Вестн. металлопромышл. (1931).
38. Г. А. Одинг. Влияние режимов резания металлов на усталостную прочность и остаточные напряжения (не опубликована).

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FTD-ID(RS)T-1264-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EFFECT OF SIZE AND SHAPE OF SPECIMENS ON THE FATIGUE LIMIT		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) I. A. Oding		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1946
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

11;13;20

DD FORM
1 JAN 73 1473   EDITION OF 1 NOV 65 IS OBSOLETE

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE	ORGANIZATION		MICROFICHE
A205	DMATC	1	E053	AF/INAKA	1
A210	DMAAC	2	E017	AF/RDXTR-W	1
B344	DIA/RDS-3C	8	E404	AEDC	1
C043	USAMIIA	1	E408	AFWL	1
C509	BALLISTIC RES LABS	1	E410	ADTC	1
C510	AIR MOBILITY R&D LAB/FIO	1	E413	ESD	2
C513	PICATINNY ARSENAL	1		FTD	
C535	AVIATION SYS COMD	1		CCN	1
C557	USAIIC	1		ETID	3
C591	FSTC	5		NIA/PHS	1
C619	MIA REDSTONE	1		NICD	5
D008	NISC	1			
H300	USAICE (USAREUR)	1			
P005	ERDA	1			
P055	CIA/CRS/ADD/SD	1			
NAVORDSTA (50L)		1			
NASA/KSI		1			
AFIT/LD		1			